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Relative strength of the 2003 and 2004 year-classes, from nearshore surveys of demersal age 0 and 1 Atlantic cod in Newman Sound, Bonavista Bay

Effectif relatif des classes d'âge de 2003 et de 2004 d'après les relevés côtiers de la morue démersale d'âge 0 et 1 dans le bras Newman, baie de Bonavista

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ABSTRACT

We surveyed demersal age 0 Atlantic cod (*Gadus morhua*) in the nearshore (<10 m deep) using a seine net to conduct a qualitative assessment of the strength of eight 1997-2004 year-classes of Atlantic cod early in their life. Our assessment was based on abundance of demersal age 0 and age 1 Atlantic cod sampled at 6-13 nearshore sites in Newman Sound, Bonavista Bay in 9 summer-autumn periods during 1995-2004. Our results were qualitatively similar to those of the geographically broader Fleming Survey (1959-64, 1992-1997, 2001) during years were the two surveys could be compared. Therefore, we have some confidence that Newman Sound data may be indicative of broader geographic patterns. Compared with the benchmark historical low in 1996 observed in several pre-recruit studies in the waters off the northeast Newfoundland coast, age 0 abundance was 10 times higher in 1998 and 40 times higher in 1999. These results suggest that the 1997, 1998, and 1999 year classes were strong compared to those in 1995 and 1996. Analysis of length frequency data collected from July to November in Newman Sound indicated that age 0 Atlantic cod settled in the nearshore in two distinct recruitment pulses in "good years" – e.g. 1998 and 1999 - the first pulse arriving in early August, the second in late September. In "bad years" – e.g. 1995 and 1996 – the first pulse has been weak and late to recruit to the nearshore. The length frequency data in years following strong age 0 recruitment also suggest that the pulse structure may remain intact through the first winter and appears to be detectable in age 1 cod the subsequent year. We have predicted (Gregory et al. 2003) that the 2000-02 year-classes of Atlantic cod will prove to be weak relative to the strong 1998 and 1999 year-classes which preceeded it. In contrast to 1997-1999, densities of age 0 Atlantic cod have been consistently low throughout much of the season in the past five years (2000-04), and were comparable to 1996, the poorest year class on record in three independent surveys of age 0 abundance off northeastern Newfoundland. The 2002 year class appeared the exhibit strong overwinter survival, showing higher than expected densities as age 1 individuals throughout 2003.

RÉSUMÉ

Nous avons effectué un relevé à la senne de la morue (*Gadus morhua*) démersale d'âge 0 dans les eaux côtières (<10 m de profondeur) afin de procéder à une évaluation qualitative de l'effectif de huit classes d'âge (1997-2004) de la morue atlantique aux premiers stades de leur vie. Notre évaluation est fondée sur l'abondance de la morue démersale d'âge 0 et 1, dont un échantillon a été prélevé dans 6 à 13 sites côtiers du bras Newman (baie de Bonavista) au cours de neuf périodes d'été-automne, de 1995 à 2004. Nos résultats étaient semblables, au plan qualitatif, à ceux du relevé Fleming, dont l'échelle géographique est plus étendue (1959 à 1964, 1992 à 1997, 2001), pour les années au cours desquelles les deux relevés ont pu être comparés. Par conséquent, nous sommes passablement convaincus que les données relatives au bras Newman seraient représentatives des tendances à une échelle géographique plus grande. Comparativement au creux historique observé en 1996 dans le cadre de plusieurs études des prérecrues au nord-est de Terre-Neuve, l'abondance de la morue d'âge 0 était respectivement 10 et 40 fois plus élevée en 1998 et en 1999. Ces résultats portent à croire que les classes d'âge de 1997, de 1998 et de 1999 étaient fortes par rapport à celles de 1995 et de 1996. L'analyse des données sur les fréquences de longueurs, recueillies de juillet à novembre dans le bras Newman, indique que la morue d'âge 0 s'est établie dans la zone côtière en deux vagues de recrutement distinctes au cours des « bonnes années » (1998 et 1999), la première au début d'août et la seconde, à la fin de septembre. Pendant les « mauvaises années » (1995 et 1996), la première vague était faible et le recrutement dans les zones côtières a tardé. Les données sur les fréquences de longueurs au cours des années suivant un fort recrutement des morues d'âge 0 montrent également que la structure des vagues de recrutement peut demeurer intacte pendant le premier hiver et semble encore décelable chez la morue d'âge 1, l'année suivante. Nous avons prédit (Gregory et coll., 2003) que les classes d'âge de morue de 2000 à 2002 seraient faibles par rapport aux fortes classes de 1998 et de 1999 qui les ont précédées. Contrairement à la période de 1997 à 1999, les densités de morues d'âge 0 sont demeurées constamment faibles pendant une grange partie de la saison au cours des cinq dernières années (2000-2004), et étaient comparables aux valeurs de 1996, année où a été observée la plus faible classe d'âge jamais enregistrée dans le cadre de trois relevés indépendants de la morue d'âge 0 effectués au nord-est de Terre-Neuve. La classe d'âge de 2002 a semblé afficher un fort taux de survie après l'hiver, les densités d'individus d'âge 1 étant plus élevées que prévu pendant toute l'année 2003.

INTRODUCTION

It has been shown, at least for the 1990's, that age 0 and age 1 Atlantic cod in 3KL (Northeast Newfoundland Shelf) are distributed predominantly in inshore waters (Dalley and Anderson 1997). Within these inshore waters during autumn, age 0 cod are most common in shallow water in the nearshore (<10 m deep - Methven and Schneider 1998). The Fleming surveys (1959-64, Lear et al. 1980; 1992-2001, e.g. Methven et al. 1998, 2003) have historically sampled nearshore abundances of age 0-2 Atlantic cod, with the objective of assessing relative year-class strength. These surveys have generally been successful at predicting the relative strength of adjacent cohorts through the first years of life (Schneider et al. 1997).

The 1997 Fleming survey (Methven et al. 1998) reported the highest abundance of age 0 cod in the nearshore during the 1992-97 period. However, the success (or failure) of the 1997 year-class could not be assessed directly the survey was not been conducted for the next three years.

Fortunately, we have access to nearshore abundance data similar to the Fleming time series in a small area within the region sampled annually by that survey. In Fall 1995, an investigation of the abundance of age 0 cod and their association with nearshore habitat types was initiated in Newman Sound, Bonavista Bay (Gotceitas et al. 1996). The 1995 study was followed by similar efforts in 1996-2002 (Gregory et al. 1997, 1999, 2000, 2002, 2004). These studies showed that the nearshore of Newman Sound represents a significant nursery area for demersal age 0 Atlantic cod. The Newman Sound studies were conducted using the same sampling techniques as the Fleming surveys; collection dates also overlapped. Therefore, the abundance data of the two surveys during the period of study were comparable, albeit at different spatial scales.

In this study, we qualitatively assessed the relative strength of the 2002-04 year-classes based on abundance of demersal age 0 Atlantic cod in the nearshore in Newman Sound, Bonavista Bay in summer and fall 2003-04. We compared abundances of age 0 and age 1 Atlantic cod in Newman Sound in 2003-04 to previous years (1995-2002), linking interannual abundance trends to those demonstrated in the Fleming surveys (1992-97, 2001). We have shown that interannual trends between the Newman Sound data and the larger geographic scale Fleming survey were consistent (Gregory et al. 2002; Methven et al. in prep.). We also present evidence that links age 0 abundance to temporal recruitment patterns within years. We suggest that in years of relatively higher recruitment, settlement occurs in more than one recruitment pulse (Methven and Bajdik 1994; Grant and Brown 1998; Gregory et al. 2003) several weeks apart; in comparison, recruitment is often limited to a single pulse in years of relatively poor recruitment. We also show that despite a detectable multiple pulse structure, all five of the year classes of this millennia appear destined to be weak relative to those of the late 90's.

METHODS

Sites sampled during the 1992-97 and 2001 Fleming surveys have been described in previous reports (e.g. Methven et al. 1998, 2003). In the 1990's, the Fleming survey was conducted at between 37-45 nearshore sites extending from St. Mary's Bay in the south to Notre Dame Bay in the north from 19 September to 27 October. In Bonavista Bay, sampling during the Fleming survey was generally 5-9 October (18 October in 1997).

Newman Sound seine sites (Fig. 1) – described in Gregory et al. (1997) – were selected on the basis of sampling logistics, and were similar to those of the Fleming survey (Lear et al. 1980). To maintain consistency among years, we have presented age 0 and age 1 abundance data from four of these sites (#1, 2, 3, and 6, Fig. 1), which were in common among our field programs in all years, 1995-2004 in Newman Sound. For comparison with the Fleming survey data, we analyzed data from Newman Sound collected only during the first two weeks of October during these years. In order to investigate seasonal growth and timing of recruitment pulses, we examined sizes of Atlantic cod captured and measured from all sites sampled in Newman Sound - September to November, 1995 (6 sites) and July to November in 1996 (9 sites), 1998-2004 (13 sites).

Both the Fleming survey and Newman Sound studies used the same sampling techniques. Fish samples were collected using a 25 m beach seine - wings and belly 19 mm stretch mesh, codend 9 mm stretch mesh bag; 24.4 m headrope, 26.2 m footrope. Aluminum poles – 75 cm long and 25 mm diameter – on each wing served to maintain the spread between the headrope and footrope. The net was deployed from a 6 m boat at a distance of 55 m from the shore, and then retrieved by two individuals standing 16 m apart on the shore. The seine was pulled along the bottom and sampled the lowest 2 m of the water column. Deployed in this manner, the net samples approximately 880 m^2 of the bottom. Less than 5% of all fish enclosed by the net are missed or escape (D. Ings, unpublished data).

All fish collected were identified and counted. Juvenile cod were assigned to tentative age groups based on previously established age-length relationships in Newfoundland waters in late autumn (age 0: $\leq$ 10 cm SL [standard length], age 1: 10-20 cm SL, and age 2: 20-30 cm SL - Dalley and Anderson 1997). We then refined these estimates by examination of length frequency trajectories through time.

RESULTS AND DISCUSSION

We observed good correspondence of age 0 and age 1 Atlantic cod abundance trends in 1995, 1996, and again in 2001 between the Fleming survey and the Newman Sound study. In both studies, 1996 showed the lowest age 0 abundance among years in the 1990's (Fig. 2). In both surveys, low abundances were seen in 2001. In the case of Newman Sound, the 2001 and 2002 age 0 abundance observations were lower than in 1996; although 2002 was better than 2001. Newman Sound abundance in 2001 was less than half of 1996, and 2002 was around 75% of that in 1996 (the previous low). The Fleming survey result for 2001, on the other hand, was similar to 1996. Similarly, age 1 abundance was higher in 1996 than it had been in 1995 in both the Fleming survey (2.0 times higher) and in Newman Sound (2.4 times higher) data sets (Fig. 3). The results of the 1997 Fleming survey led Methven (1998) to predicted that age 1 abundance in 1998 would be higher than in previous years of the Fleming survey in the 1990s. Age 1 abundance observed in Newman Sound in 1998 was higher than in 1995 and 1996 qualitatively supporting this prediction (Fig. 3). Age 0 Atlantic cod abundance in Newman Sound was over an order of magnitude higher in 1998 and 40-times higher in 1999 than in 1996. Abundance of age 0 Atlantic cod in 1996 was the lowest recorded in three independant prerecruit studies in the 1990s (1992-97 Fleming - Methven 1998, 1992-99 NE Newfoundland Shelf - Dalley et al. 2000, 1995-2000 Newman Sound – Gregory et al. 2002). We suggest that the 2000-04 year classes will be weak compared to the final two years of the 1990's, and will be similar or worse that 1996, with the 1999 year-class remaining the strongest cohort since the implementation of the 1992 moratorium.

Age 0 Atlantic cod appear to recruit (=settle) into nearshore habitats in a recruitment pattern consisting of a number of settlement pulses each year. Analysis of size distribution of age 0 Atlantic cod collected July to November in Newman Sound indicated that age 0 cod settled in only a single recruitment pulse in 1996 (Fig. 4). Similarly, we identified only a single Atlantic cod recruitment pulse in 1995 (Gotceitas et al. 1996), although sampling in Newman Sound only started in late September that year, making definitive statements regarding pulse structure somewhat tenuous. In contrast, both 1998 (Fig. 5) and 1999 (Fig. 6) age 0 Atlantic cod recruited to the nearshore in two or more recruitment pulses - the first arriving in late-July to early-August, the second in September. In 1998, the first pulse was the strongest, whereas the two pulses were equally weighted in 1999 (Fig. 6). In 2000-02, recruitment to the nearshore was late (late-August and early September) compared to previous years; although there was evidence of multiple modes in the length frequency (Fig. 7-9). Overall abundances in 2000 were low – only slightly higher than 1996 – and were even lower than the 1996 benchmark in 2001 and 2002. There was evidence of multiple recruitment pulses in as many as three or four separate "events" (Fig. 7-10).

The pulse structure established for age 0 cod in any given year appears to be maintained in the size structure of age 1 cod in the subsequent year. Evidence of

a multiple pulse recruitment pattern was present in both 1996 (Fig. 4) and 1998 (Fig. 5). However, the evidence was especially compelling among age 1 fish in 1999 (Fig. 6) when we examined data on the same year-class (1998) in two consecutive years - as age 0 in 1998 (Fig. 5) and as age 1 in 1999 (Fig. 6). The two pulses of the 1999 year class although readily apparent, were only weakly separated in time and size frequency (Fig. 6), possibly explaining why the pulse structure among age 1 Atlantic cod in 2000 was poorly defined (Fig. 7). In comparison, there was no pulse structure apparent for the 2000-2002 year classes when they were 1 year old (2000 cohort - Fig 8, 2001 cohort - Fig 9, 2002 cohort – Fig. 10).

We have not explored fully the ecological implications of multiple recruitment pulses on year-class strength. The data in this study suggest that a complex pulse structure (e.g. two or more modes) may signal a relatively good recruitment year compared to a simple or weak pulse structure (e.g. one mode). From genetic evidence, we do know that different stock components contributed differentially to each of these pulses in 1999 (Beacham et al. 2000). We do not yet know if the multiple recruitment patterns we observed in Newman Sound are restricted to individual sites. However, we do know that similar recruitment patterns occur annually at other sites along the northeast Newfoundland coast (Methven and Bajdik 1994, Grant and Brown 1998) suggesting that these observations reflect broader geographic phenomena. Although the ecological implications of complex recruitment pulse structure remain to be worked out, these implications could be substantive. Size-selective mortality factors should effect differential survival between individuals from different recruitment pulses (Sogard 1997).

Based on the results of this study, we make the following conclusions:

- we reinforce our prediction from 2001 (Gregory et al. 2002) that the 1999 year class will be strong relative to other year classes before or after it in our time series, now including the 2003-04 year classes;

- we predict that the 2003 and 2004 year-class will be very weak, possibly even worse than the 1996 year-class – the benchmark low; and,

- and apparent strong overwinter survival age 0 - age 1 may significantly modify the strength of the 2002 year-class.

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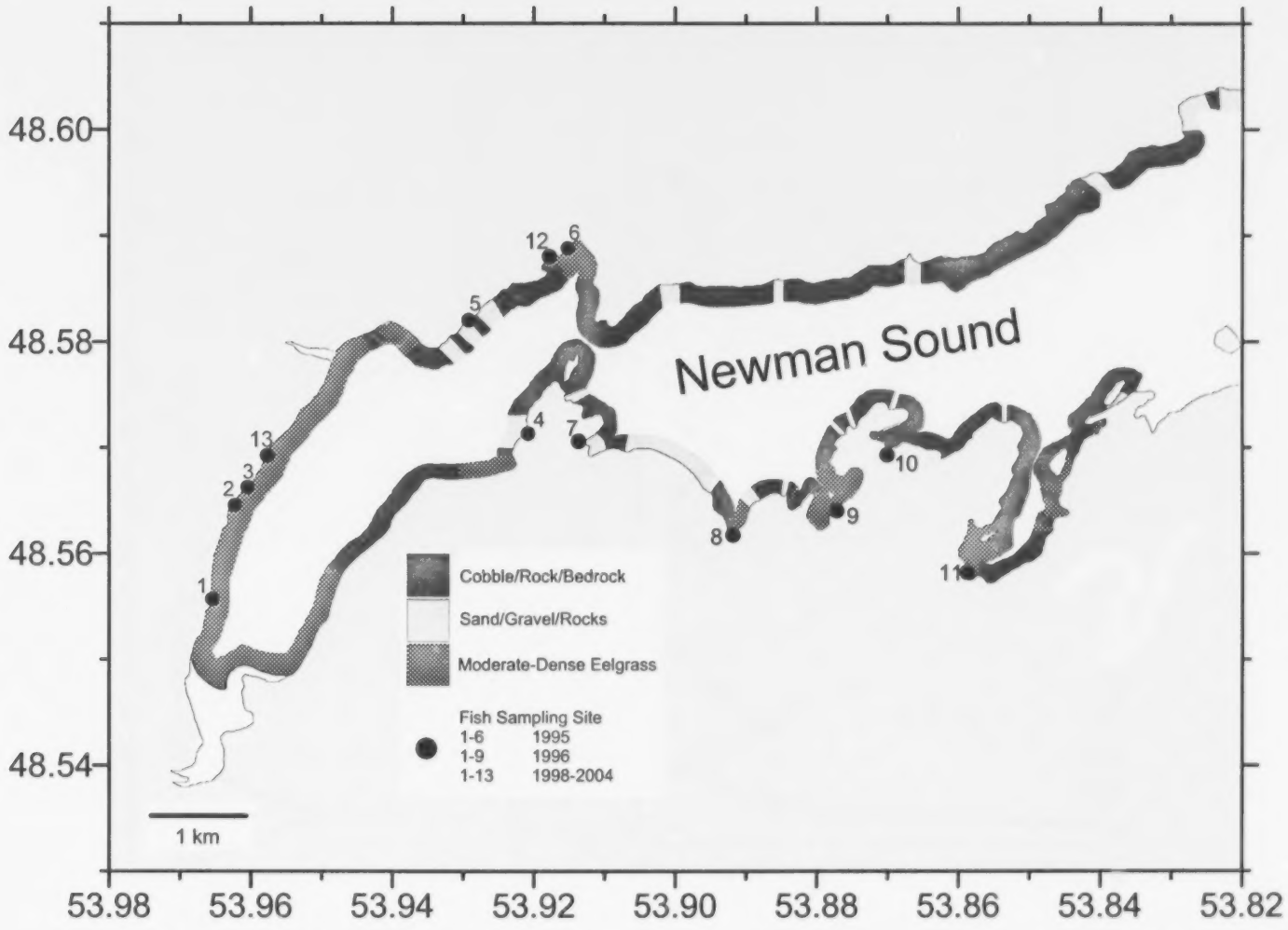

Figure 1. Location of sampling sites and nearshore habitat in Newman Sound, Bonavista Bay July to November 1995-2004.

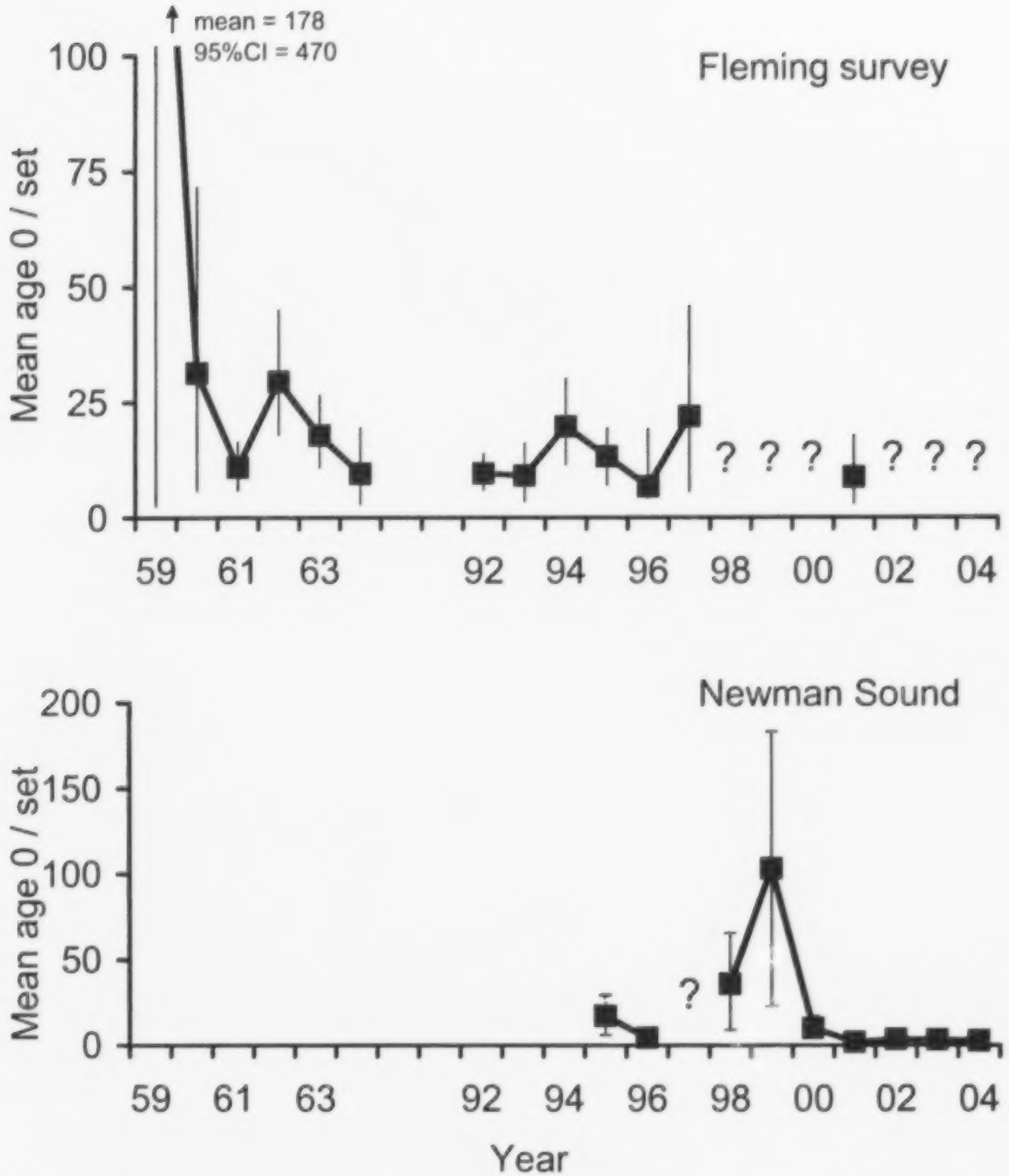

Figure 2. Mean age 0 Atlantic cod abundance (mean/set) caught by beach seine in the Fleming survey 1959-64 and 1992-2001, St. Mary's Bay to Notre Dame Bay (upper panel) and in Newman Sound Bonavista Bay, 1995-2004 (lower panel). Vertical bars are 95% confidence intervals estimated by randomized data resampling.

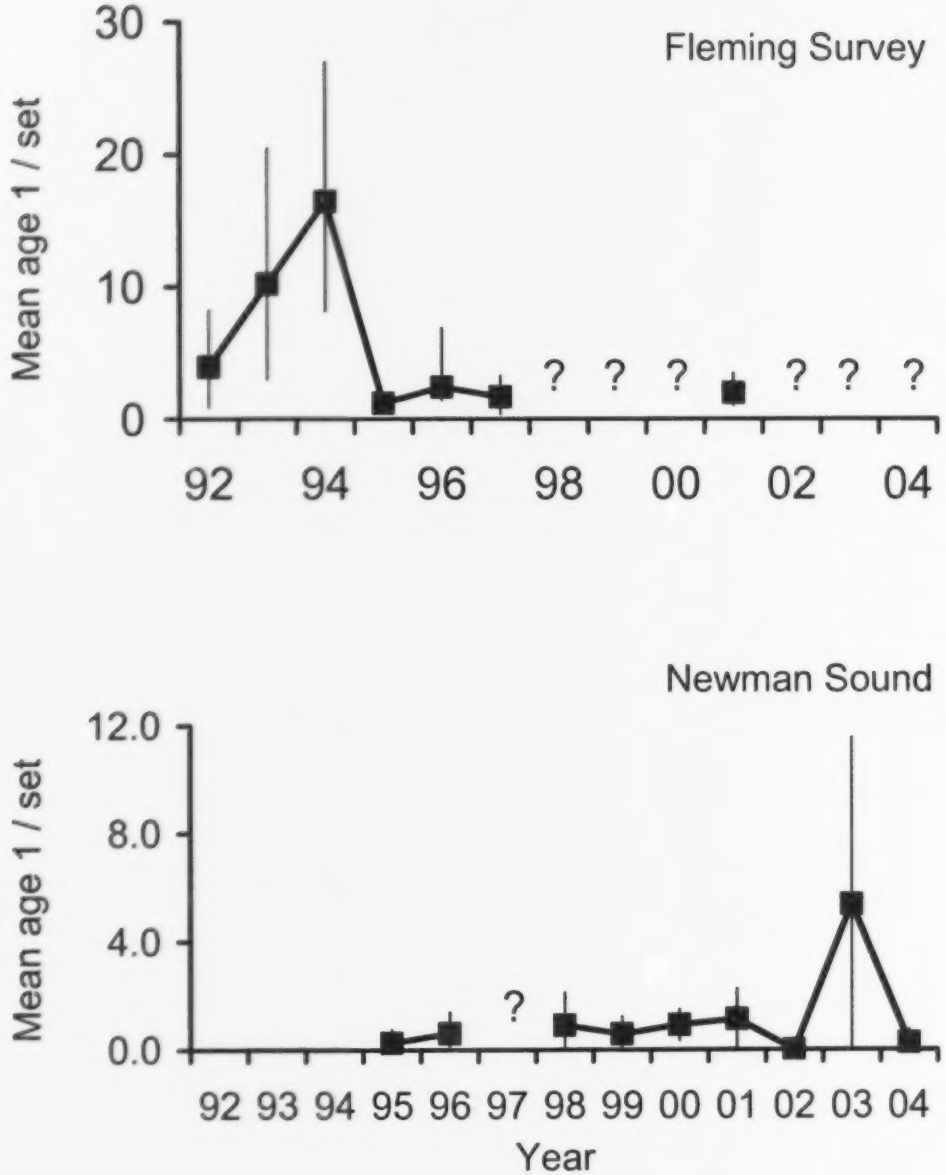

Figure 3. Mean age 1 Atlantic cod abundance (mean/set) caught by beach seine in the Fleming survey 1992-2001, St. Mary's Bay to Notre Dame Bay (upper panel) and in Newman Sound Bonavista Bay, 1995-2004 (lower panel). Vertical bars are 95% confidence intervals estimated by randomized data resampling.

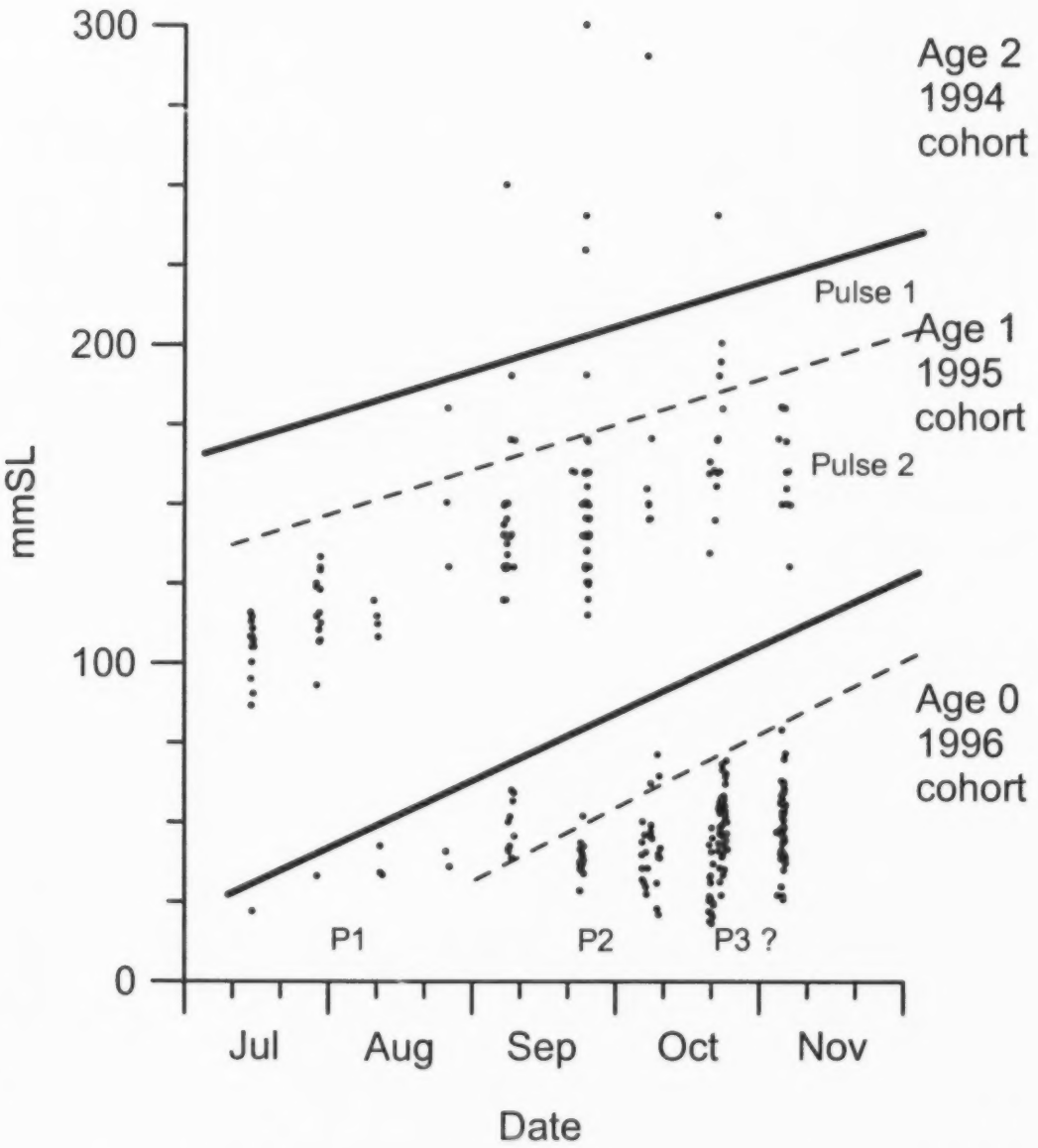

Figure 4. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 1996 and their potential age and recruitment pulse structure.

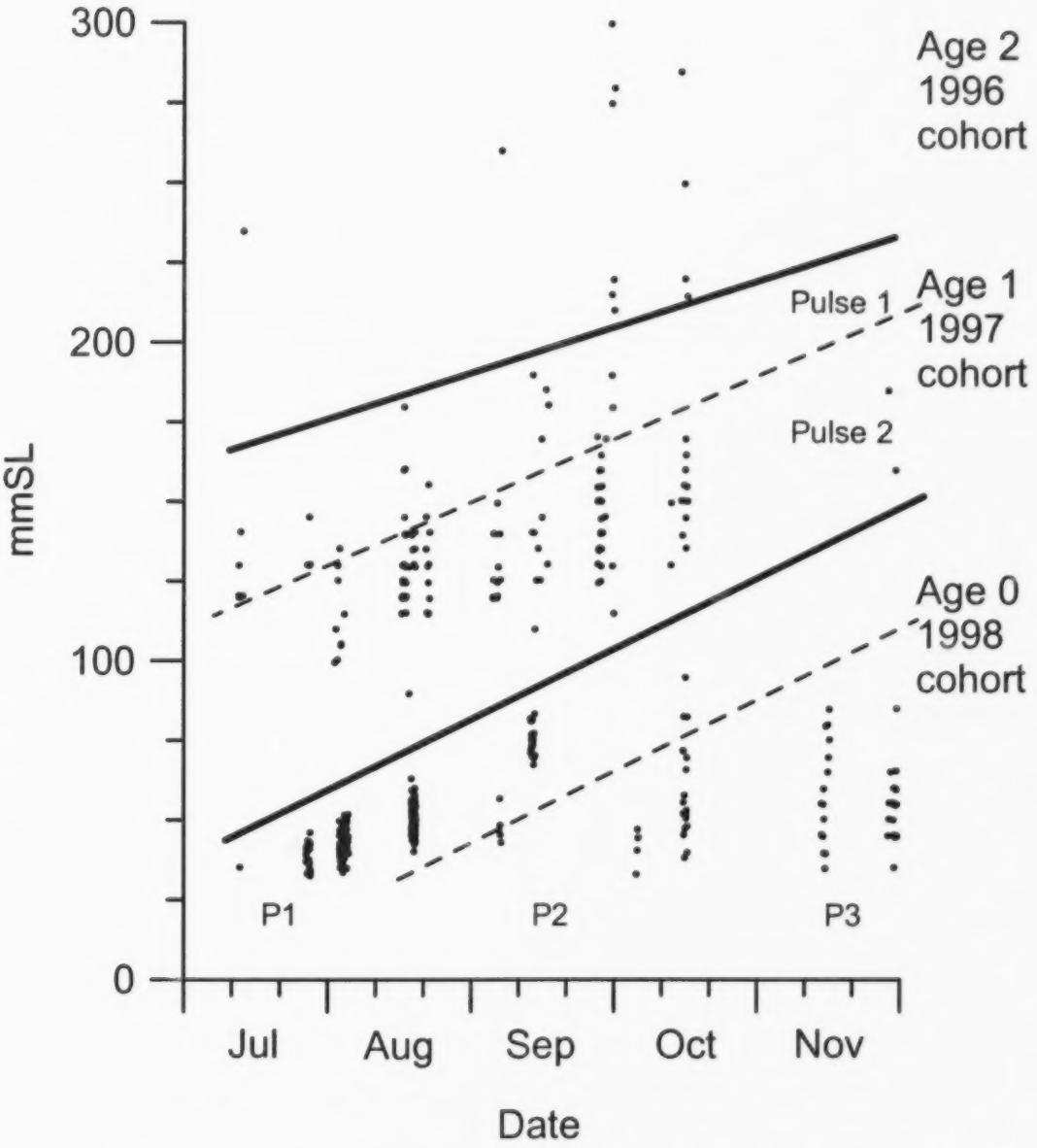

Figure 5. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 1998 and their potential age and recruitment pulse structure.

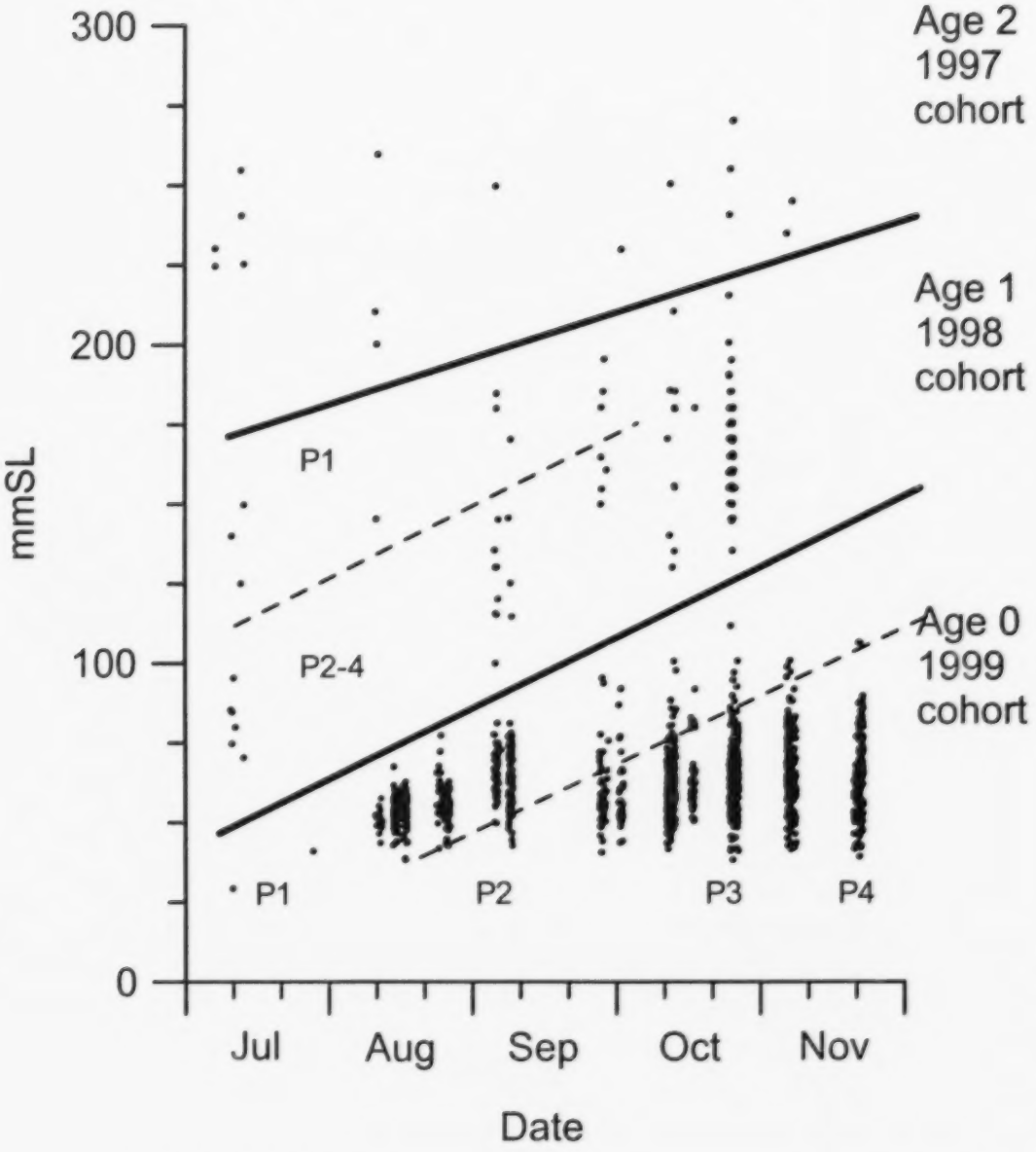

Figure 6. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 1999 and their potential age and recruitment pulse structure.

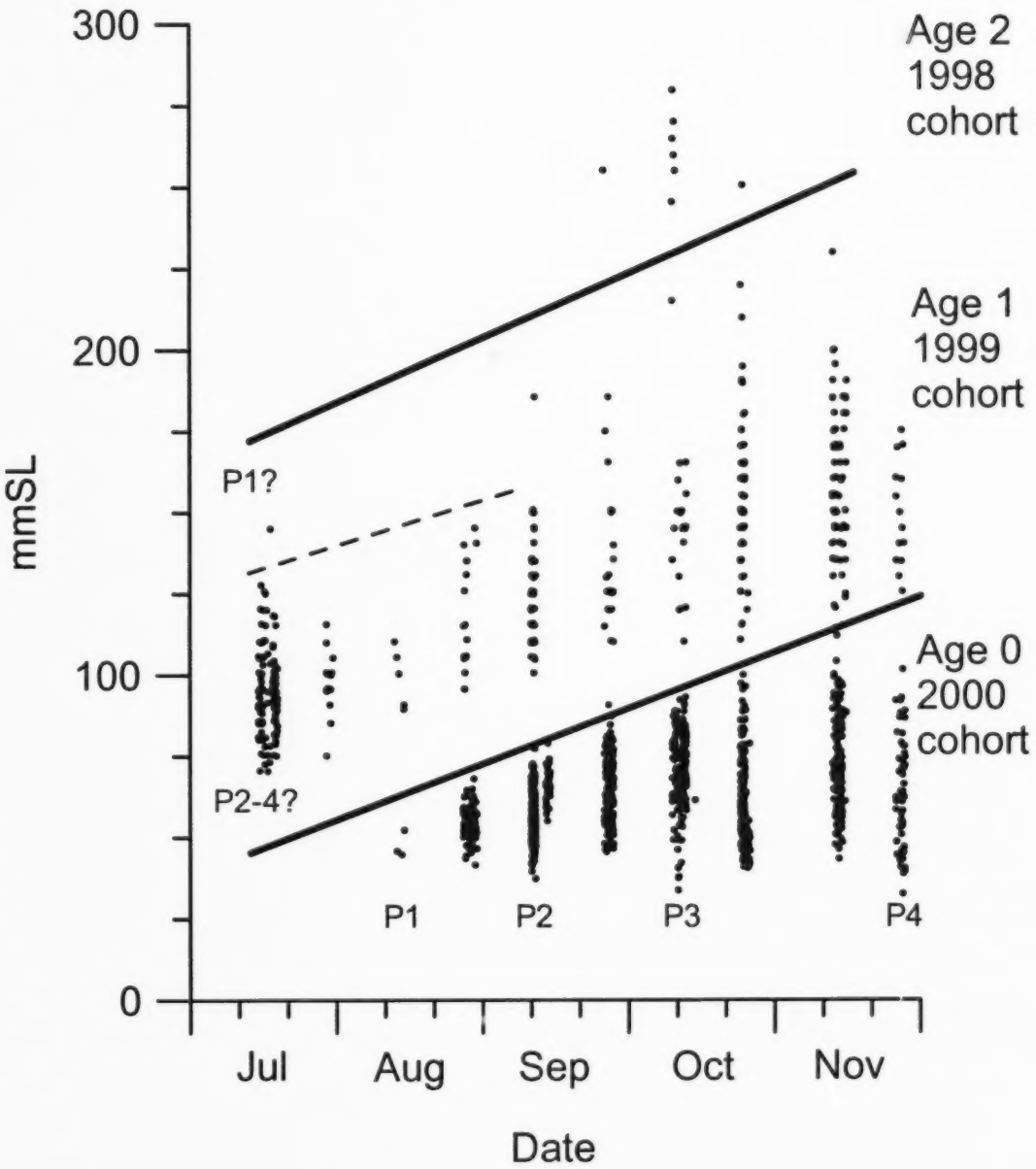

Figure 7. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 2000 and their potential age and recruitment pulse structure.

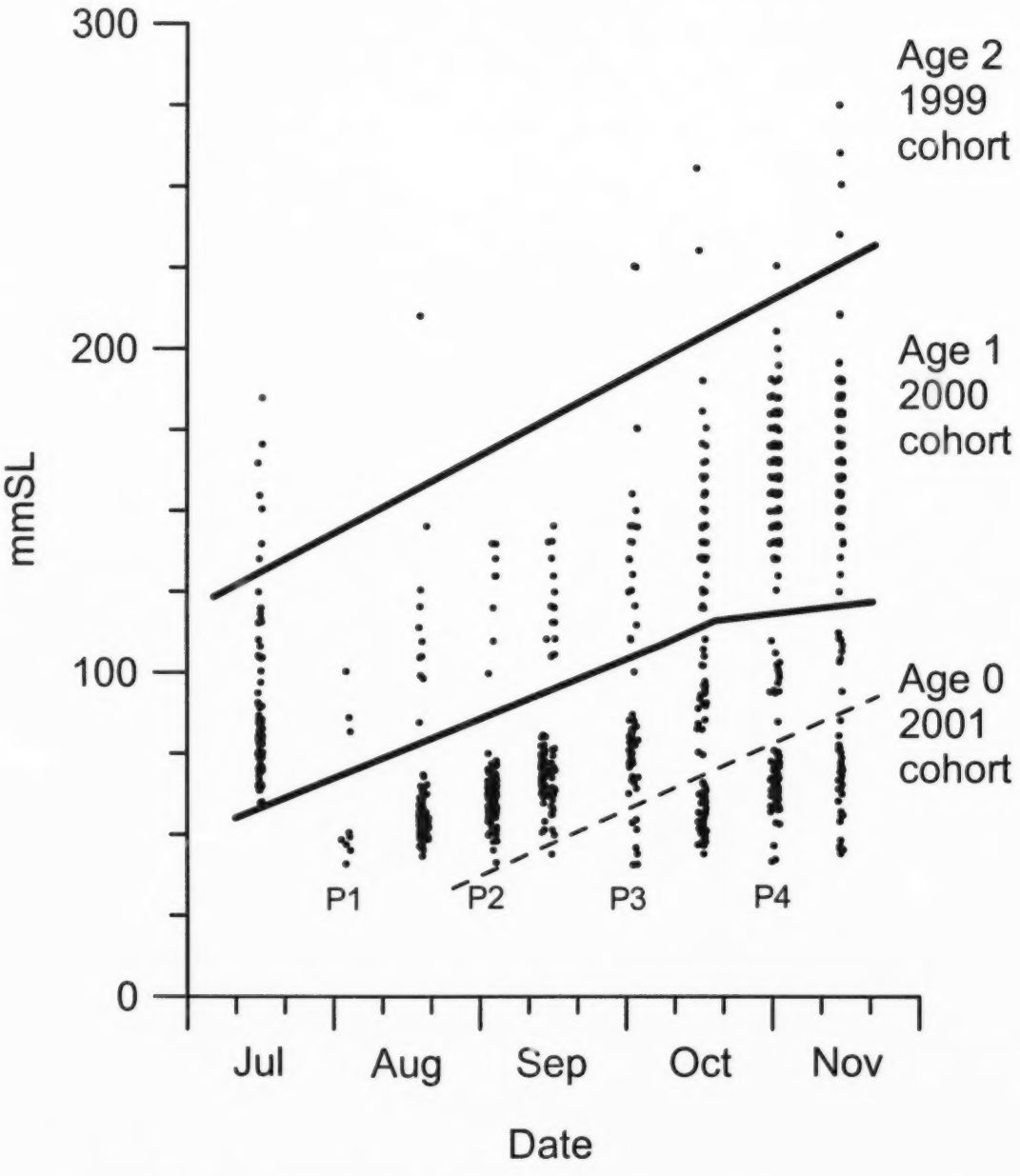

Figure 8. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 2001 and their potential age and recruitment pulse structure.

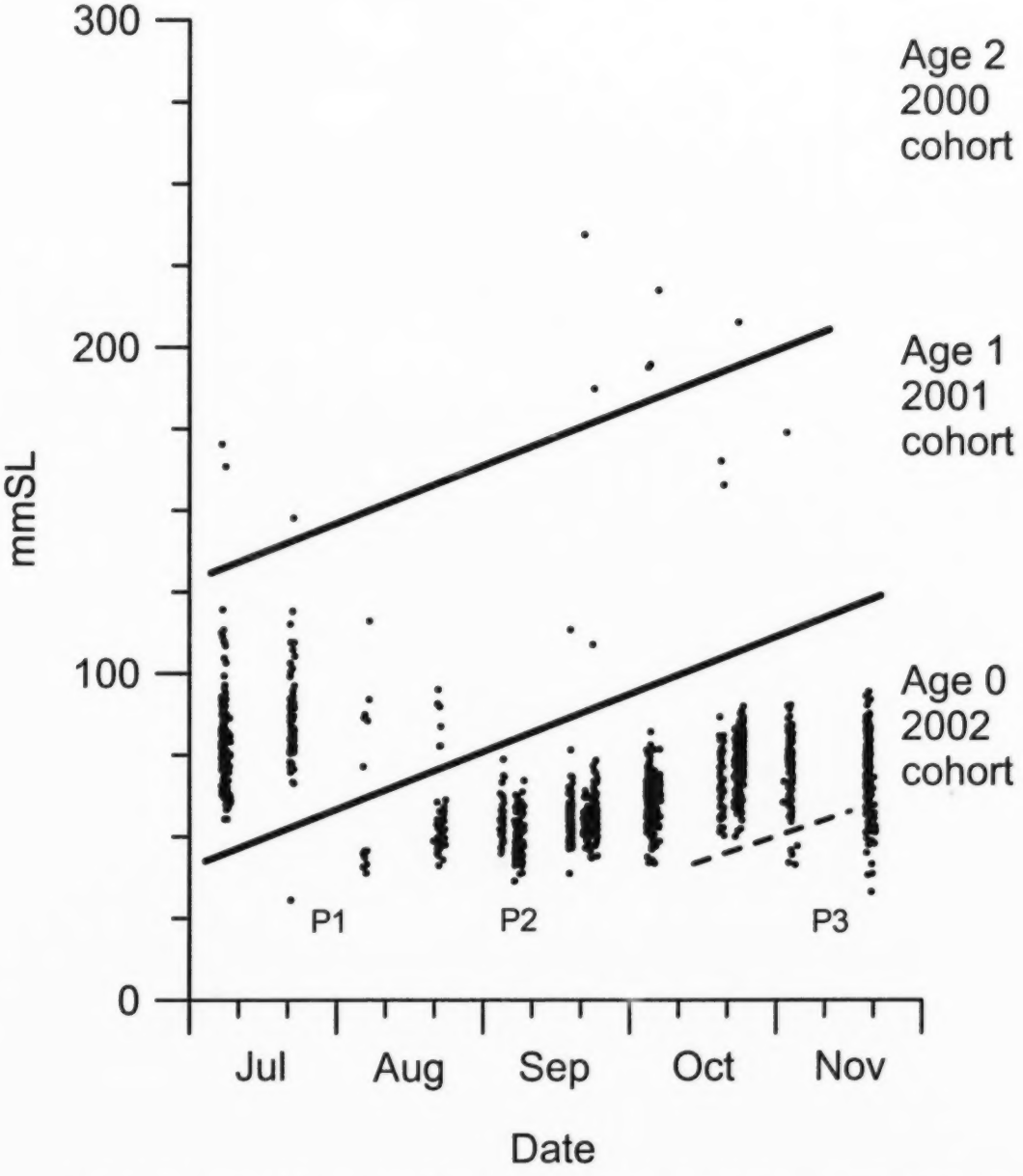

Figure 9. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 2002 and their potential age and recruitment pulse structure.

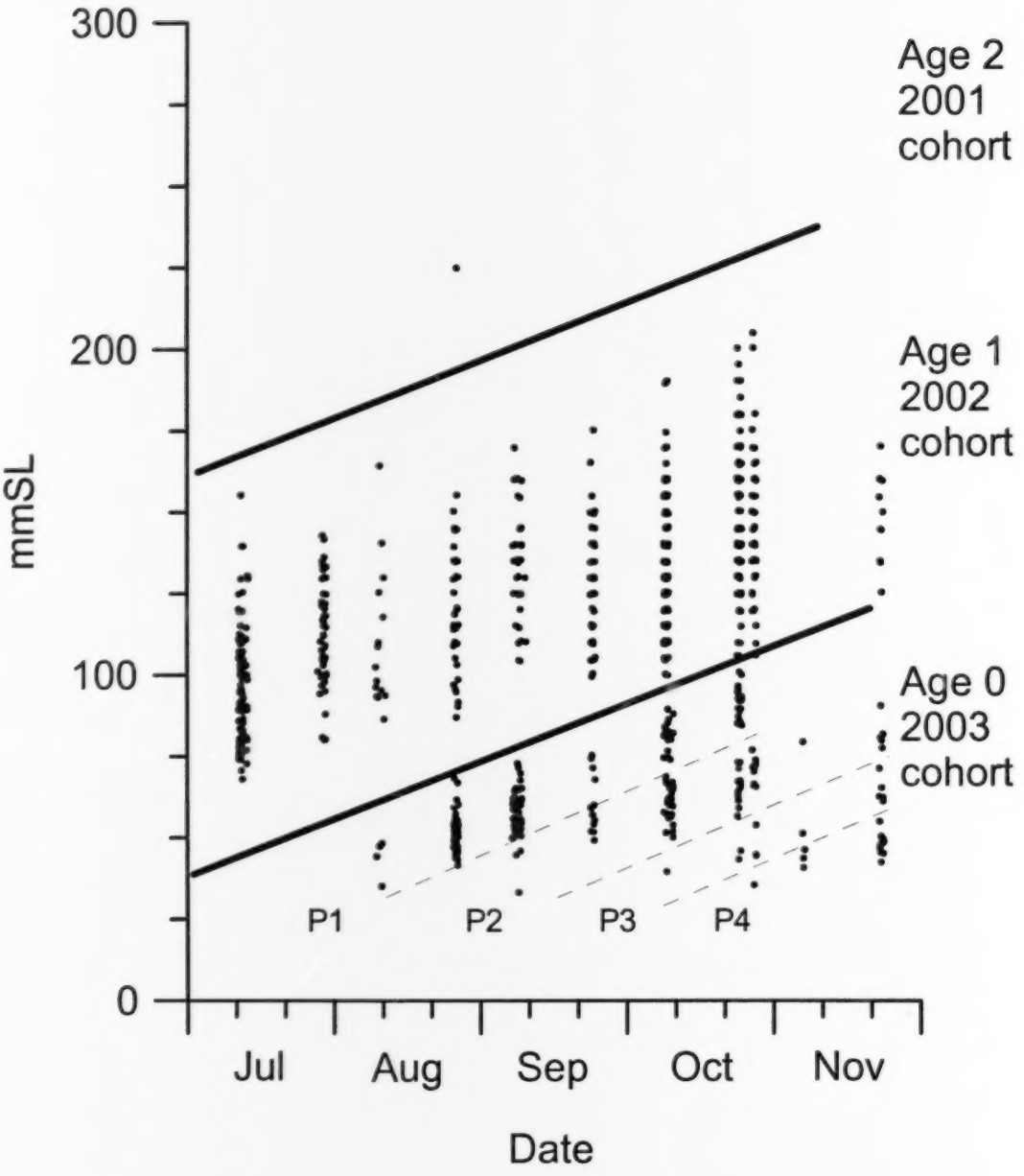

Figure 10. Sizes of Atlantic cod captured by beach seine in Newman Sound, Bonavista Bay, July - November, 2003 and their potential age and recruitment pulse structure.